## **CONTENTS**

| PR | EFACE  |           |   | xvii  |
|----|--------|-----------|---|-------|
| AC | KNOW   | LEDGM     | ENTS  | xxi   |
| SY | MBOL 9 |           | NOTATIONS   | xxiii |
| 01 | IVIDOL | 5711101   | VO I/ (I I O I VO   | XXIII |
| 1  | INTRO  | DUCTION   | v , C   | 1     |
|    | 1.1    | Historica | 1 Use of Foundations / 1  |       |
|    | 1.2    | Kinds of  | Foundations and their Uses / 1  |       |
|    |        | 1.2.1     | Spread Footings and Mats / 1  |       |
|    |        | 1.2.2     | Deep Foundations / 4  |       |
|    |        | 1.2.3     | Hybrid Foundations / 7  |       |
|    | 1.3    | Concepts  | s in Design / 7   |       |
|    |        | 1.3.1     | Visit the Site / 7  |       |
|    |        | 1.3.2     | Obtain Information on Geology at Site / 7                               |       |
|    |        | 1.3.3     | Obtain Information on Magnitude and Nature of Loads on Foundation / 8   |       |
|    |        | 1.3.4     | Obtain Information on Properties of Soil at Site / 8                    |       |
|    |        | 1.3.5     | Consider Long-Term Effects / 9  |       |
|    |        | 1.3.6     | Pay Attention to Analysis / 9   |       |
|    |        | 1.3.7     | Provide Recommendations for Tests of Deep Foundations / 9               |       |
|    |        | 1.3.8     | Observe the Behavior of the Foundation of a<br>Completed Structure / 10 |       |

Problems / 10

|   | 11001                 | cilis / To                       |   |    |
|---|-----------------------|----------------------------------|---|----|
| 2 | ENGI                  | IEERING GEOLOGY                  | A   | 11 |
|   | 2.1 Introduction / 11 |                                  |   |    |
|   | 2.2                   | Nature of Soil Affecte           | d by Geologic Processes / 12                |    |
|   |                       | 2.2.1 Nature of Tr               | ansported Soil / 12                         |    |
|   |                       | 2.2.2 Weathering                 | and Residual Soil / 14                      |    |
|   |                       |                                  | oil Affected by Volcanic                    |    |
|   |                       | Processes /                      | 14  |    |
|   |                       | 2.2.4 Nature of G                | aciated Soil / 15                           |    |
|   |                       | 2.2.5 Karst Geolog               | gy / 16                                     |    |
|   | 2.3                   | -                                | gions in the United States / 16             |    |
|   | 2.4                   | U.S. Geological Surve            | y and State Agencies / 17                   |    |
|   | 2.5                   |                                  | ication of Engineering Geology / 18         |    |
|   | 2.6                   | Site Visit / 19                  |   |    |
|   | Probl                 | ems / 19                         |   |    |
| 3 | FUND                  | AMENTALS OF SOIL I               | MECHANICS                                   | 21 |
|   | 3.1                   | Introduction / 21                |   |    |
|   | 3.2                   | Data Needed for the I            | Design of Foundations / 21                  |    |
|   |                       | 3.2.1 Soil and Roo               | ck Classification / 22                      |    |
|   |                       | 3.2.2 Position of t              | he Water Table / 22                         |    |
|   |                       | 3.2.3 Shear Streng               | th and Density / 23                         |    |
|   |                       | 3.2.4 Deformabilit               | y Characteristics / 23                      |    |
|   |                       | 3.2.5 Prediction of Environment  | Changes in Conditions and the / 24          |    |
|   | 3.3                   | Nature of Soil / 24              |   |    |
|   |                       | 3.3.1 Grain-Size I               | Distribution / 24                           |    |
|   |                       | 3.3.2 Types of Soil              | l and Rock / 26                             |    |
|   |                       |                                  | of Common Geologic Materials / 26           | )  |
|   |                       | 3.3.4 Water Conte                | nt and Void Ratio / 30                      |    |
|   |                       | 3.3.5 Saturation of              | Soil / 31                                   |    |
|   |                       | 3.3.6 Weight-Volu                | ime Relationships / 31                      |    |
|   |                       | 3.3.7 Atterberg Li<br>System / 3 | mits and the Unified Soils Classification 4 | on |
|   | 3.4                   | Concept of Effective S           | Stress / 37                                 |    |
|   |                       | •                                | Cests for Consolidation of Soils / 39       |    |
|   |                       | 3.4.2 Spring and I               | Piston Model of Consolidation / 42          |    |
|   |                       | 3.4.3 Determination              | on of Initial Total Stresses / 45           |    |
|   |                       | 3.4.4 Calculation                | of Total and Effective Stresses / 47        |    |

|        | 3.4.5     | The Role of Effective Stress in Soil Mechanics / 49            |
|--------|-----------|--|
| 3.5    | Analysis  | of Consolidation and Settlement / 49                           |
|        | 3.5.1     | Time Rates of Settlement / 49                                  |
|        | 3.5.2     | One-Dimensional Consolidation Testing / 57                     |
|        | 3.5.3     | The Consolidation Curve / 64                                   |
|        | 3.5.4     | Calculation of Total Settlement / 67                           |
|        | 3.5.5     | Calculation of Settlement Due to<br>Consolidation / 68         |
|        | 3.5.6     | Reconstruction of the Field Consolidation<br>Curve / 69        |
|        | 3.5.7     | Effects of Sample Disturbance on Consolidation Properties / 73 |
|        | 3.5.8     | Correlation of Consolidation Indices with Index<br>Tests / 78  |
|        | 3.5.9     | Comments on Accuracy of Settlement<br>Computations / 80        |
| 3.6    | Shear Str | rength of Soils / 81   |
|        | 3.6.1     | Introduction / 81  |
|        | 3.6.2     | Friction Between Two Surfaces in Contact / 81                  |
|        | 3.6.3     | Direct Shear Testing / 84                                      |
|        | 3.6.4     | Triaxial Shear Testing / 84                                    |
|        | 3.6.5     | Drained Triaxial Tests on Sand / 89                            |
|        | 3.6.6     | Triaxial Shear Testing of Saturated Clays / 92                 |
|        | 3.6.7     | The SHANSEP Method / 119                                       |
|        | 3.6.8     | Other Types of Shear Testing for Soils / 122                   |
|        | 3.6.9     | Selection of the Appropriate Testing Method / 123              |
| Proble | ms / 124  |  |
| INVES  | TIGATION  | OF SUBSURFACE CONDITIONS 134                                   |
| 4.1    | Introduct | ion / 134  |
| 4.2    | Methods   | of Advancing Borings / 136                                     |
|        | 4.2.1     | Wash-Boring Technique / 136                                    |
|        | 4.2.2     | Continuous-Flight Auger with Hollow Core / 137                 |
| 4.3    | Methods   | of Sampling / 139  |
|        | 4.3.1     | Introduction / 139   |
|        | 4.3.2     | Sampling with Thin-Walled Tubes / 139                          |
|        | 4.3.3     | Sampling with Thick-Walled Tubes / 142                         |
|        | 4.3.4     | Sampling Rock / 142  |

4

4.4

The Role of Effective Stress in Soil

In Situ Testing of Soil / 144

|   |        | 4.4.1         | Cone Penetrometer and Piezometer-Cone<br>Penetrometer / 144 |     |
|---|--------|---------------|---|-----|
|   |        | 4.4.2         | Vane Shear Device / 146                                     |     |
|   |        |               |   |     |
|   | 15     |               | Pressuremeter / 148   |     |
|   | 4.5    | $\mathcal{C}$ | Report / 152  |     |
|   | 4.6    | ms / 155      | ace Investigations for Offshore Structures / 153            |     |
|   | Fioble | 1118 / 133    |   |     |
| 5 | PRINC  | CIPAL TY      | PES OF FOUNDATIONS  | 158 |
|   | 5.1    | Shallow       | Foundations / 158   |     |
|   | 5.2    | Deep Fo       | oundations / 160  |     |
|   |        | 5.2.1         | Introduction / 160  |     |
|   |        | 5.2.2         | Driven Piles with Impact Hammer / 160                       |     |
|   |        | 5.2.3         | Drilled Shafts / 162  |     |
|   |        |               | Augercast Piles / 168                                       |     |
|   |        | 5.2.5         | GeoJet Piles / 170  |     |
|   |        |               | Micropiles / 172  |     |
|   | 5.3    | Caisson       | s / 172   |     |
|   | 5.4    | Hybrid        | Foundation / 173  |     |
|   | Proble | ms / 175      | $O_{\lambda}$   |     |
| 6 | DESIG  | NING ST       | TABLE FOUNDATIONS   | 176 |
|   | 6.1    | Introduc      | etion / 176   |     |
|   | 6.2    | Total an      | d Differential Settlement / 177                             |     |
|   | 6.3    | Allowab       | ble Settlement of Structures / 178                          |     |
|   |        | 6.3.1         | Tolerance of Buildings to Settlement / 178                  |     |
|   |        | 6.3.2         | Exceptional Case of Settlement / 178                        |     |
|   |        | 6.3.3         | Problems in Proving Settlement / 180                        |     |
|   | 6.4    | Soil Inv      | estigations Appropriate to Design / 180                     |     |
|   |        | 6.4.1         | Planning / 180  |     |
|   |        | 6.4.2         | Favorable Profiles / 181                                    |     |
|   |        | 6.4.3         | Soils with Special Characteristics / 181                    |     |
|   |        | 6.4.4         | Calcareous Soil / 182                                       |     |
|   | 6.5    |               | Valid Analytical Methods / 186                              |     |
|   |        | 6.5.1         | Oil Tank in Norway / 187                                    |     |
|   |        | 6.5.2         | Transcona Elevator in Canada / 187                          |     |
|   |        | 6.5.3         | Bearing Piles in China / 188                                |     |
|   | 6.6    |               | ions at Unstable Slopes / 189                               |     |
|   |        | 6.6.1         | Pendleton Levee / 189                                       |     |
|   |        | 6.6.2         | Fort Peck Dam / 190   |     |

| 6.7     | Effects of Installation on the Quality of Deep Foundations / 190                                 |
|---------|--|
|         | 6.7.1 Introduction / 190   |
| 6.8     | Effects of Installation of Deep Foundations on Nearby<br>Structures / 192                        |
|         | 6.8.1 Driving Piles / 192  |
| 6.9     | Effects of Excavations on Nearby Structures / 193  |
| 6.10    | Deleterious Effects of the Environment on Foundations / 194                                      |
| 6.11    | Scour of Soil at Foundations / 194   |
| Probler | ms / 194   |
| THEOF   | RIES OF BEARING CAPACITY AND SETTLEMENT 196  |
| 7.1     | Introduction / 196   |
| 7.2     | Terzaghi's Equations for Bearing Capacity / 198  |
| 7.3     | Revised Equations for Bearing Capacity / 199   |
| 7.4     | Extended Formulas for Bearing Capacity by J. Brinch  |
|         | Hansen / 200   |
|         | 7.4.1 Eccentricity / 203   |
|         | 7.4.2 Load Inclination Factors / 204   |
|         | 7.4.3 Base and Ground Inclination / 205  |
|         | 7.4.4 Shape Factors / 205  |
|         | 7.4.5 Depth Effect / 206   |
|         | 7.4.6 Depth Factors / 206  |
|         | 7.4.7 General Formulas / 208   |
|         | 7.4.8 Passive Earth Pressure / 208   |
|         | 7.4.9 Soil Parameters / 209  |
|         | 7.4.10 Example Computations / 209  |
| 7.5     | Equations for Computing Consolidation Settlement of Shallow Foundations on Saturated Clays / 213 |
|         | 7.5.1 Introduction / 213   |
|         | 7.5.2 Prediction of Total Settlement Due to Loading of Clay Below the Water Table / 214          |
|         | 7.5.3 Prediction of Time Rate of Settlement Due to Loading of Clay Below the Water Table / 219   |
| Probler | ms / 222   |
| PRINC   | IPLES FOR THE DESIGN OF FOUNDATIONS 223  |

7

Fundamental Principles / 223

Standards of Professional Conduct / 223

Introduction / 223

8.2.1

8.1 8.2

## **X** CONTENTS

9

|        | 8.2.2      | Fundamental Canons / 224                                  |
|--------|------------|---|
| 8.3    | Design 7   | Геат / 224  |
| 8.4    | Codes a    | nd Standards / 225  |
| 8.5    | Details of | of the Project / 225                                      |
| 8.6    | Factor o   | f Safety / 226  |
|        | 8.6.1      | Selection of a Global Factor of Safety / 228              |
|        | 8.6.2      | Selection of Partial Factors of Safety / 229              |
| 8.7    | Design 1   | Process / 230   |
| 8.8    | Specifica  | ations and Inspection of the Project / 231                |
| 8.9    | Observa    | tion of the Completed Structure / 232                     |
| Proble | ms / 233   |   |
| Appen  | dix 8.1 /  | 234   |
| GEOT   | ECHNIC/    | AL DESIGN OF SHALLOW FOUNDATIONS 235                      |
| 9.1    | Introduc   | tion / 235  |
| 9.2    | Problem    | s with Subsidence / 235                                   |
| 9.3    | Designs    | to Accommodate Construction / 237                         |
|        | 9.3.1      | Dewatering During Construction / 237                      |
|        | 9.3.2      | Dealing with Nearby Structures / 237                      |
| 9.4    | Shallow    | Foundations on Sand / 238                                 |
|        | 9.4.1      | Introduction / 238  |
|        | 9.4.2      | Immediate Settlement of Shallow Foundations on Sand / 239 |
|        | 9.4.3      | Bearing Capacity of Footings on Sand / 244                |
|        | 9.4.4      | Design of Rafts on Sand / 247                             |
| 9.5    | Shallow    | Foundations on Clay / 247                                 |
|        | 9.5.1      | Settlement from Consolidation / 247                       |
|        | 9.5.2      | Immediate Settlement of Shallow Foundations on Clay / 251 |
|        | 9.5.3      | Design of Shallow Foundations on Clay / 253               |
|        | 9.5.4      | Design of Rafts / 255                                     |
| 9.6    | Shallow    | Foundations Subjected to Vibratory Loading / 255          |
| 9.7    | Designs    | in Special Circumstances / 257                            |
|        | 9.7.1      | Freezing Weather / 257                                    |
|        | 9.7.2      | Design of Shallow Foundations on Collapsible Soil / 260   |
|        | 9.7.3      | Design of Shallow Foundations on Expansive Clay / 260     |
|        | 9.7.4      | Design of Shallow Foundations on Layered Soil / 262       |

323

Analysis of a Response of a Strip Footing by Finite

Element Method / 263

| 10.1   | Comme               | nt on the Nature of the Problem / 270                                    |
|--------|---------------------|--|
| 10.1   |                     | s of Computation / 273   |
| 10.2   | 10.2.1              | Behavior of Axially Loaded Piles / 273                                   |
|        | 10.2.1              | Geotechnical Capacity of Axially Loaded Piles / 275                      |
| 10.3   |                     | quation for Computing the Ultimate Geotechnical y of a Single Pile / 277 |
|        | 10.3.1              | API Methods / 277  |
|        |                     | Revised Lambda Method / 284  |
|        |                     | U.S. Army Corps Method / 286   |
|        | 10.3.4              |  |
| 10.4   |                     | ng the Load–Settlement Relationship of an Axially Pile / 297             |
|        | 10.4.1              | Methods of Analysis / 297  |
|        | 10.4.2              | Interpretation of Load-Settlement Curves / 303                           |
| 10.5   | Investigated Method | ation of Results Based on the Proposed Computation / 306                 |
| 10.6   | Example             | e Problems / 307   |
|        | 10.6.1              | Skin Friction / 308  |
| 10.7   | -                   | s of Pile Driving / 312  |
|        | 10.7.1              | Introduction / 312   |
|        | 10.7.2              | Dynamic Formulas / 313   |
|        | 10.7.3              | Reasons for the Problems with Dynamic Formulas / 314                     |
|        | 10.7.4              | Dynamic Analysis by the Wave Equation / 315                              |
|        | 10.7.5              | Effects of Pile Driving / 317  |
|        | 10.7.6              | Effects of Time After Pile Driving with No Load / 320                    |
| Proble | ms / 321            |  |
|        |                     | AL DESIGN OF DRILLED SHAFTS UNDER  |

9.7.5

**AXIAL LOADING** 

11.1

11.2

Introduction / 323

Presentation of the FHWA Design Procedure / 323

|         | 11.2.1                | Introduction / 323  |
|---------|-----------------------|---|
| 11.3    | Strength              | and Serviceability Requirements / 324   |
|         | 11.3.1                | General Requirements / 324  |
|         | 11.3.2                | Stability Analysis / 324  |
|         | 11.3.3                | Strength Requirements / 324   |
| 11.4    | Design C              | Criteria / 325  |
|         | 11.4.1                | Applicability and Deviations / 325  |
|         | 11.4.2                | Loading Conditions / 325  |
|         | 11.4.3                | Allowable Stresses / 325  |
| 11.5    | General 6<br>Shafts / | Computations for Axial Capacity of Individual Drilled 325                                 |
| 11.6    | Design E<br>Uplift /  | Equations for Axial Capacity in Compression and in 326                                    |
|         | 11.6.1                | Description of Soil and Rock for Axial Capacity<br>Computations / 326                     |
|         | 11.6.2                | Design for Axial Capacity in Cohesive Soils / 326   |
|         | 11.6.3                | Design for Axial Capacity in Cohesionless<br>Soils / 334                                  |
|         | 11.6.4                | Design for Axial Capacity in Cohesive Intermediate<br>Geomaterials and Jointed Rock / 345 |
|         | 11.6.5                | Design for Axial Capacity in Cohesionless<br>Intermediate Geomaterials / 362              |
|         | 11.6.6                | Design for Axial Capacity in Massive Rock / 365   |
|         | 11.6.7                | Addition of Side Resistance and End Bearing in Rock / 374                                 |
|         | 11.6.8                | Commentary on Design for Axial Capacity in Karst / 375                                    |
|         | 11.6.9                | Comparison of Results from Theory and Experiment / 376                                    |
| Probler | ms / 377              | -   |
| FUNDA   | MENTAL                | CONCEPTS REGARDING DEEP   |

FOUNDATIONS UNDER LATERAL LOADING
12.1 Introduction / 379

12

12.1.1 Description of the Problem / 379

12.1.2 Occurrence of Piles Under Lateral Loading / 379

379

12.1.3 Historical Comment / 381

12.2 Derivation of the Differential Equation / 382

12.2.1 Solution of the Reduced Form of the Differential Equation / 386

|    | 12.6    |           | Solution Using Nondimensional Charts for Analysis gle Pile / 401                 |
|----|---------|-----------|--|
|    | Probler | ms / 411  |  |
| 13 |         |           | NDIVIDUAL DEEP FOUNDATIONS UNDER<br>G USING t-z MODEL 413                        |
|    | 13.1    | Short-Te  | rm Settlement and Uplift / 413   |
|    |         | 13.1.1    | Settlement and Uplift Movements / 413  |
|    |         | 13.1.2    | Basic Equations / 414  |
|    |         | 13.1.3    | Finite Difference Equations / 417  |
|    |         | 13.1.4    | Load-Transfer Curves / 417   |
|    |         | 13.1.5    | Load-Transfer Curves for Side Resistance in Cohesive Soil / 418                  |
|    |         | 13.1.6    | Load-Transfer Curves for End Bearing in Cohesive Soil / 419                      |
|    |         | 13.1.7    | Load-Transfer Curves for Side Resistance in<br>Cohesionless Soil / 421           |
|    |         | 13.1.8    | Load-Transfer Curves for End Bearing in<br>Cohesionless Soil / 425               |
|    |         | 13.1.9    | Load-Transfer Curves for Cohesionless Intermediated<br>Geomaterials / 426        |
|    |         | 13.1.10   | Example Problem / 430  |
|    |         | 13.1.11   | Experimental Techniques for Obtaining Load-Transfer Versus Movement Curves / 436 |
|    | 13.2    |           | or Vertical Ground Movements Due to Downdrag or ve Uplift / 437                  |
|    |         | 13.2.1    | Downward Movement Due to Downdrag / 438  |
|    |         | 13.2.2    | Upward Movement Due to Expansive Uplift / 439                                    |
|    | Probler | ms / 440  |  |
| 14 |         |           | DESIGN BY COMPUTER OR PILES DILATERAL LOADING 441                                |
|    | 14.1    | Nature o  | f the Comprehensive Problem / 441  |
|    | 14.2    | Different | ial Equation for a Comprehensive Solution / 442                                  |

Response of Soil to Lateral Loading / 393

Effect of the Nature of Loading on the Response of Soil / 396 Method of Analysis for Introductory Solutions for a Single

12.3

12.4

12.5

14.3

14.3.1

Pile / 397

Introduction / 443

Recommendations for p-y Curves for Soil and Rock / 443

|    |              | 14.3.2   | Recommendations for <i>p-y</i> Curves for Clays / 447  |
|----|--------------|--|--|
|    |              | 14.3.3   | Recommendations for <i>p-y</i> Curves for Sands / 464  |
|    |              | 14.3.4   | Modifications to <i>p-y</i> Curves for Sloping Ground / 473  |
|    |              | 14.3.5   | Modifications for Raked (Battered Piles) / 477   |
|    |              | 14.3.6   | Recommendations for <i>p-y</i> Curves for Rock / 478   |
|    | 14.4         | Solution   | of the Differential Equation by Computer / 484   |
|    |              | 14.4.1   | Introduction / 484   |
|    |              | 14.4.2   | Formulation of the Equation by Finite Differences / 486  |
|    |              | 14.4.3   | Equations for Boundary Conditions for Useful Solutions / 487   |
|    | 14.5         | Impleme  | entation of Computer Code / 489  |
|    |              | 14.5.1   | Selection of the Length of the Increment / 490   |
|    |              | 14.5.2   | Safe Penetration of Pile with No Axial Load / 491  |
|    |              | 14.5.3   | Buckling of a Pipe Extending Above the Groundline / 492  |
|    |              | 14.5.4   | Steel Pile Supporting a Retaining Wall / 492   |
|    |              | 14.5.5   | Drilled Shaft Supporting an Overhead   |
|    |              |  | Structure / 496  |
|    | Proble       | ms / 499   | (/)  |
| 15 | ANALY        | SIS OF I   | PILE GROUPS 503  |
|    | 15.1         | Introduc   | tion / 503   |
|    | 15.2         |  | tion of Load to Piles in a Group: The mensional Problem / 503  |
|    |              | 15.2.1   | Model of the Problem / 504   |
|    |              |  |  |
|    |              | 15.2.2   | Detailed Step-by-Step Solution Procedure / 510   |
|    | 15.3         |  |  |
|    | 15.3<br>15.4 | Modifica<br>Example  | Detailed Step-by-Step Solution Procedure / 510   |
|    |              | Modifica<br>Example  | Detailed Step-by-Step Solution Procedure / 510 ation of <i>p-y</i> Curves for Battered Piles / 510 e Solution Showing Distribution of a Load to Piles in a   |
|    |              | Modifica<br>Example<br>Two-Dir<br>15.4.1                                   | Detailed Step-by-Step Solution Procedure / 510 ation of <i>p-y</i> Curves for Battered Piles / 510 a Solution Showing Distribution of a Load to Piles in a mensional Group / 511   |
|    | 15.4         | Modifica<br>Example<br>Two-Dir<br>15.4.1                                   | Detailed Step-by-Step Solution Procedure / 510 ation of <i>p-y</i> Curves for Battered Piles / 510 e Solution Showing Distribution of a Load to Piles in a mensional Group / 511 Solution by Hand Computations / 511   |
|    | 15.4         | Modifica<br>Example<br>Two-Dir<br>15.4.1<br>Efficience                     | Detailed Step-by-Step Solution Procedure / 510 ation of <i>p-y</i> Curves for Battered Piles / 510 a Solution Showing Distribution of a Load to Piles in a mensional Group / 511 Solution by Hand Computations / 511 by of Piles in Groups Under Lateral Loading / 517 Modifying Lateral Resistance of Closely Spaced  |
|    | 15.4         | Modifica<br>Example<br>Two-Dir<br>15.4.1<br>Efficience<br>15.5.1           | Detailed Step-by-Step Solution Procedure / 510 ation of <i>p</i> -y Curves for Battered Piles / 510 a Solution Showing Distribution of a Load to Piles in a mensional Group / 511 Solution by Hand Computations / 511 by of Piles in Groups Under Lateral Loading / 517 Modifying Lateral Resistance of Closely Spaced Piles / 517 Customary Methods of Adjusting Lateral Resistance   |
|    | 15.4         | Modifica<br>Example<br>Two-Dir<br>15.4.1<br>Efficience<br>15.5.1<br>15.5.2 | Detailed Step-by-Step Solution Procedure / 510 ation of <i>p</i> -y Curves for Battered Piles / 510 a Solution Showing Distribution of a Load to Piles in a mensional Group / 511 Solution by Hand Computations / 511 by of Piles in Groups Under Lateral Loading / 517 Modifying Lateral Resistance of Closely Spaced Piles / 517 Customary Methods of Adjusting Lateral Resistance for Close Spacing / 518 Adjusting for Close Spacing under Lateral Loading |

|         | 15.6.2   | Soils / 529  |     |
|---------|----------|--|-----|
|         | 15.6.3   | Efficiency of Piles in a Group in Cohesive Soils / 531 |     |
|         | 15.6.4   | Concluding Comments / 534                              |     |
| Probler | ms / 535 | • (/   |     |
| APPENDI | X        |  | 537 |
| REFEREN | ICES     |  | 539 |
| NDEX    |          |  | 559 |
|         |          |  |     |
|         |          |  |     |
|         |          |  |     |
|         |          |  |     |
|         |          |  |     |
|         |          | $O_1$  |     |
|         |          |  |     |
|         |          |  |     |
|         |          |  |     |
|         |          |  |     |
|         |          |  |     |
|         |          |  |     |
|         |          |  |     |
|         |          |  |     |
|         |          |  |     |
|         |          |  |     |